



US005806319A

United States Patent [19]

[11] Patent Number: **5,806,319**

Wary et al.

[45] Date of Patent: **Sep. 15, 1998**

[54] METHOD AND APPARATUS FOR CRYOGENICALLY COOLING A DEPOSITION CHAMBER

(List continued on next page.)

[76] Inventors: **John Wary**, 119 Cherokee La., Noblesville, Ind. 46060; **Roger A. Olson**, 313 George St., Amery, Wis. 54001; **William F. Beach**, 1007 Severin Dr., Bridgewater, N.J. 08807; **Walter Swanson**, 47 Haytown Rd., Lebanon, N.J. 08833

OTHER PUBLICATIONS

Journal of Vacuum Science and Technology A11(6)(1993).
L. You, et al., Chemical Perspectives of Microelectronic Materials III Symposium (1992).
J. Apl. Pol. Sci., 13, 2325 Chow, et al.
Chow, S.W., "Poly ($\alpha,\alpha,\alpha',\alpha'$ -tetrafluoro-p-xylylene)", *Journal of Applied Polymer Science*, vol. 13, pp. 2325-2332, 1969.
You, L. et al., "Vapor Deposition fo Parylene Films From Precursors", *Chemical Perspectives of Microelectronic Materials III Symposium*.
Mikami Takashi, "Quartz Crystal Oscillator Type Radical Beam Monitor", *Patent Abstracts of Japan*, Patent No. 07050258.
International Search Report.

[21] Appl. No.: **816,295**

[22] Filed: **Mar. 13, 1997**

[51] Int. Cl.⁶ **B01D 8/00**

[52] U.S. Cl. **62/55.5; 417/901**

[58] Field of Search **62/55.5; 417/901**

[56] References Cited

U.S. PATENT DOCUMENTS

3,211,128	10/1965	Potter et al. .	
3,246,627	4/1966	Loeb et al. .	
3,262,279	7/1966	Moore, Jr.	62/55.5
3,301,707	1/1967	Loeb et al. .	
3,310,955	3/1967	Snedden, Jr. et al.	62/55.5
3,360,949	1/1968	Blanchard et al.	62/55.5
3,364,654	1/1968	Westbrook	62/55.5
3,371,499	3/1968	Hagenbach et al.	62/55.5
3,472,795	10/1969	Tittmann et al. .	
3,554,512	1/1971	Elliott .	
3,570,449	3/1971	Blecherman .	
3,573,968	4/1971	Loeb .	
3,600,216	8/1971	Stewart .	
3,667,424	6/1972	Cornelius et al. .	
3,670,693	6/1972	Rorick et al. .	
3,712,074	1/1973	Boissin	62/55.5
3,747,558	7/1973	Harel .	

FOREIGN PATENT DOCUMENTS

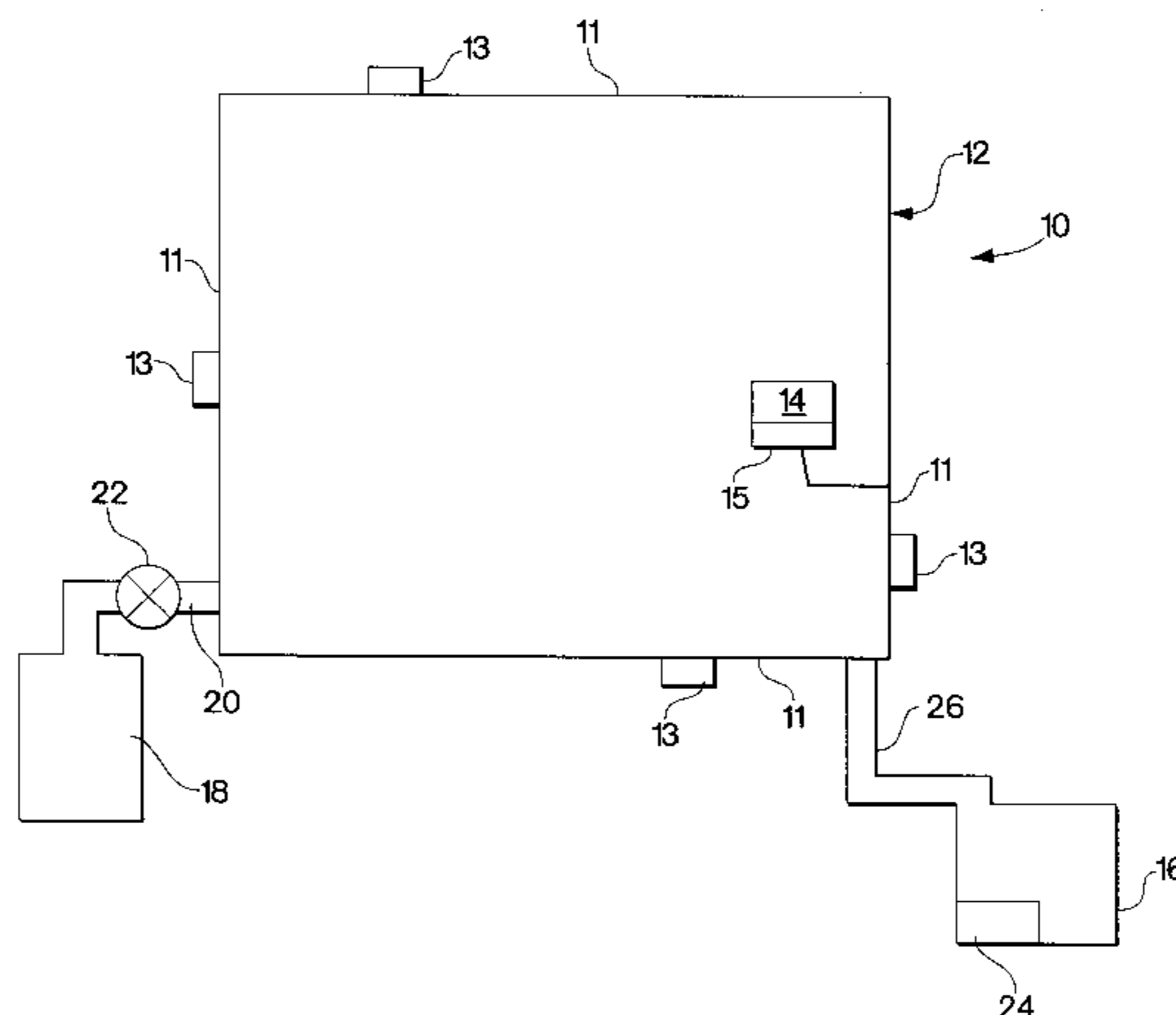
0 102 417 A1	3/1984	European Pat. Off. .
0 434 227 A1	6/1991	European Pat. Off. .
0 679 373 A2	11/1995	European Pat. Off. .
650947	3/1951	United Kingdom .
A1145005	3/1965	United Kingdom .
WO 82/03069	9/1982	WIPO .

Primary Examiner—Ronald C. Capossela
Attorney, Agent, or Firm—Mintz, Levin, Cohn, Ferris, Glovsky and Popeo, P.C.

[57] ABSTRACT

A method and apparatus for depositing parylene monomer within the interior of a deposition chamber of a parylene deposition system. In certain embodiments, the method comprises the steps of: (a) introducing a cryogenic fluid into the interior of the deposition chamber to cool the surface of the substrate; and (b) introducing the parylene monomer into the interior of the chamber to deposit the parylene monomer onto the surface of the substrate. In some embodiments, the apparatus comprises: a deposition chamber; a pumping system, a source of cryogenic fluid, a gas source and at least one support mount disposed within the interior of the deposition chamber. The pumping system reduces the pressure of the interior of the deposition chamber, and the pumping system is in fluid communication with the interior of the deposition chamber. The source of cryogenic fluid is in fluid communication with the interior of the deposition chamber. The gas source is in fluid communication with the interior of the deposition chamber. Optionally, the method or apparatus may include the use of a load lock chamber.

53 Claims, 4 Drawing Sheets



U.S. PATENT DOCUMENTS

3,749,601	7/1973	Tittle .	5,091,207	2/1992	Tanaka .
3,769,806	11/1973	Boissin 62/55.5	5,112,642	5/1992	Wajid .
4,110,392	8/1978	Yamazaki .	5,121,707	6/1992	Kanoo .
4,184,188	1/1980	Briglia .	5,123,375	6/1992	Hansen .
4,261,762	4/1981	King .	5,129,360	7/1992	Ahern et al. .
4,323,031	4/1982	Kaplan .	5,151,133	9/1992	Ohmine et al. .
4,362,125	12/1982	Schadler .	5,167,717	12/1992	Boitnott .
4,401,052	8/1983	Baron et al. .	5,186,120	2/1993	Ohnishi et al. .
4,468,283	8/1984	Ahmed .	5,217,755	6/1993	Thebault et al. .
4,495,889	1/1985	Riley .	5,221,403	6/1993	Nozawa et al. .
4,508,055	4/1985	Elton et al. .	5,228,501	7/1993	Tepman et al. .
4,518,623	5/1985	Riley .	5,248,370	9/1993	Tsui et al. .
4,577,465	3/1986	Olsen et al. .	5,248,380	9/1993	Tanaka .
4,596,208	6/1986	Wolfson et al. .	5,250,092	10/1993	Nakano .
4,613,306	9/1986	Bauer et al. .	5,250,323	10/1993	Miyazaki .
4,619,844	10/1986	Pierce et al. .	5,254,171	10/1993	Hayakawa et al. .
4,683,143	7/1987	Riley .	5,261,963	11/1993	Basta et al. .
4,734,533	3/1988	Ungarelli et al. .	5,262,194	11/1993	Bischer, Jr. et al. .
4,761,269	8/1988	Conger et al. .	5,264,039	11/1993	Gobush et al. .
4,783,561	11/1988	Pregaglia et al. .	5,266,118	11/1993	Mitra .
4,795,838	1/1989	Bornengo et al. .	5,268,033	12/1993	Stewart .
4,816,608	3/1989	Bornengo et al. .	5,268,202	12/1993	You et al. .
4,846,998	7/1989	Pohl et al. .	5,270,266	12/1993	Hirano et al. .
4,853,488	8/1989	Ungarelli et al. .	5,292,554	3/1994	Sinha et al. .
4,877,433	10/1989	Oshitari .	5,302,767	4/1994	Galley et al. .
4,883,020	11/1989	Kasai et al. .	5,324,540	6/1994	Terada .
4,886,923	12/1989	Ungarelli et al. .	5,344,492	9/1994	Sato et al. .
4,902,572	2/1990	Horne et al. .	5,350,453	9/1994	Schlosser .
4,903,754	2/1990	Hirscher et al. .	5,401,316	3/1995	Shiraishi et al. .
4,945,856	8/1990	Stewart .	5,439,525	8/1995	Peichl et al. .
4,957,781	9/1990	Kanegae et al. .	5,447,799	9/1995	Loh et al. .
5,002,011	3/1991	Ohmine et al. .	5,458,687	10/1995	Shichida et al. .
5,007,372	4/1991	Hattori et al. .	5,470,802	11/1995	Gnade et al. .
5,015,503	5/1991	Varrin, Jr. et al. .	5,534,068	7/1996	Beach et al. .
5,078,091	1/1992	Stewart .	5,536,317	7/1996	Crain et al. .
5,078,851	1/1992	Nishihata et al. .	5,536,321	7/1996	Olson et al. .
5,079,045	1/1992	Luhmann et al. .	5,536,322	7/1996	Wary et al. .
5,088,444	2/1992	Ohmine et al. .	5,556,473	9/1996	Olson et al. .

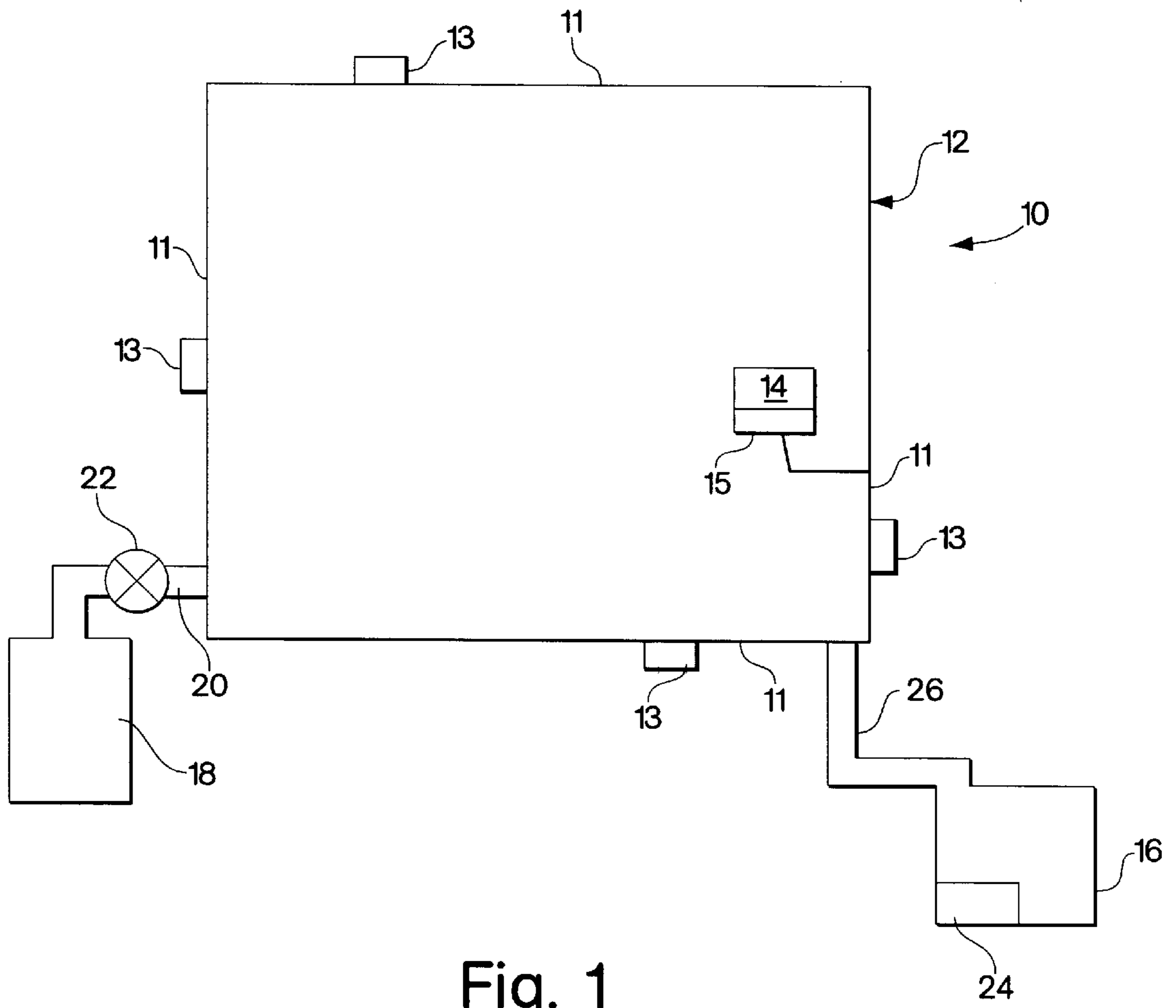


Fig. 1

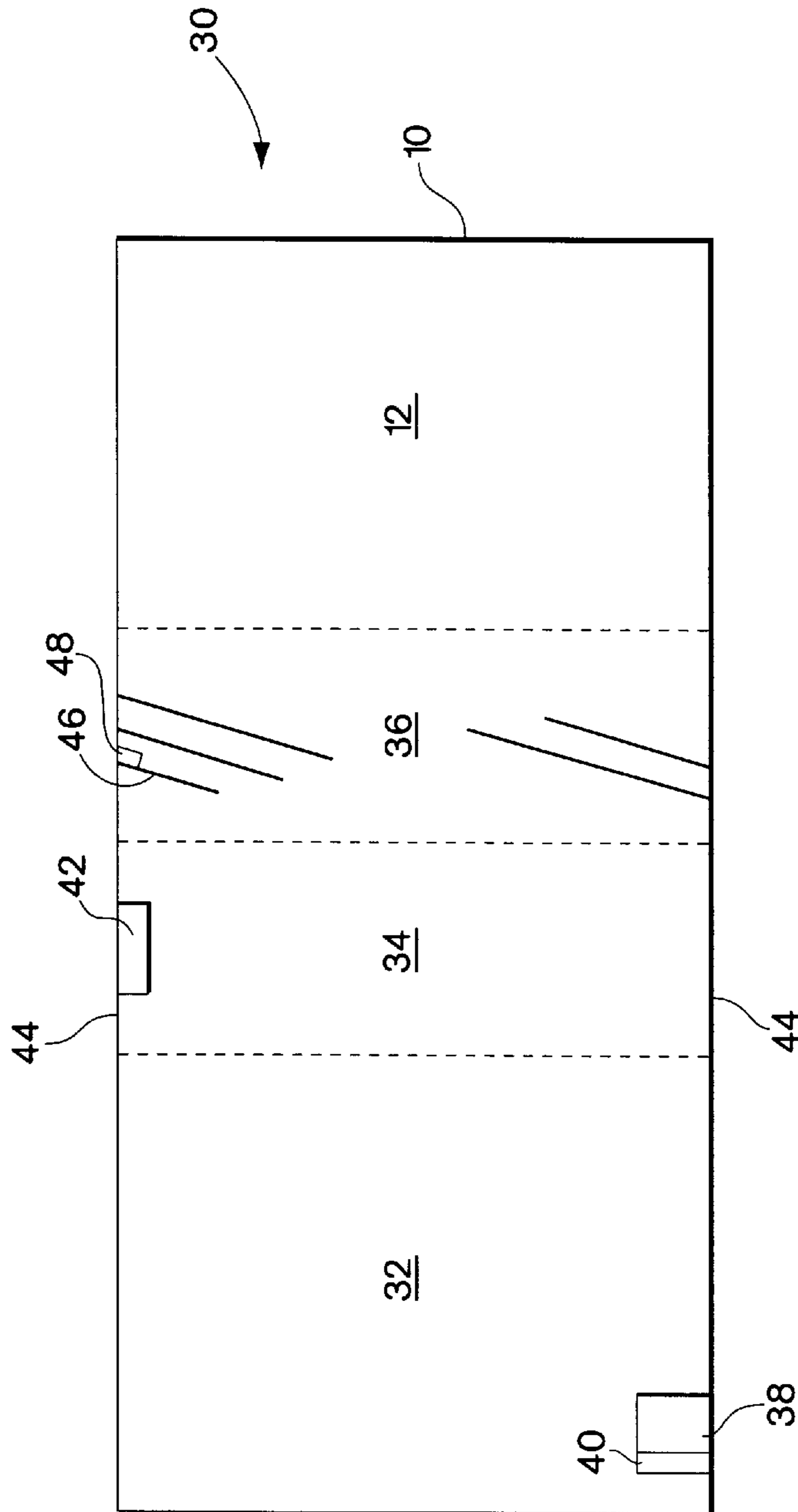


Fig. 2

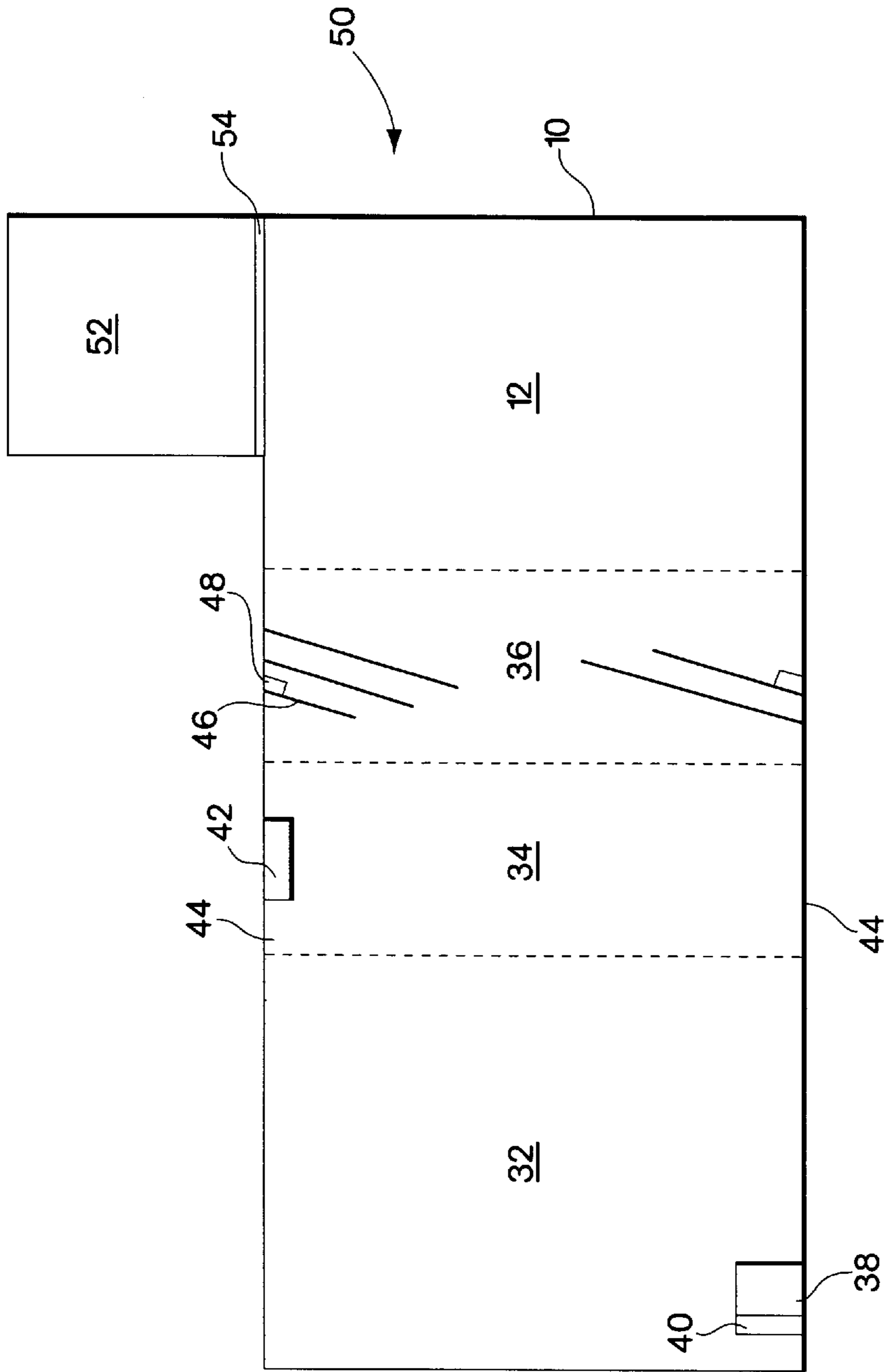


Fig. 3

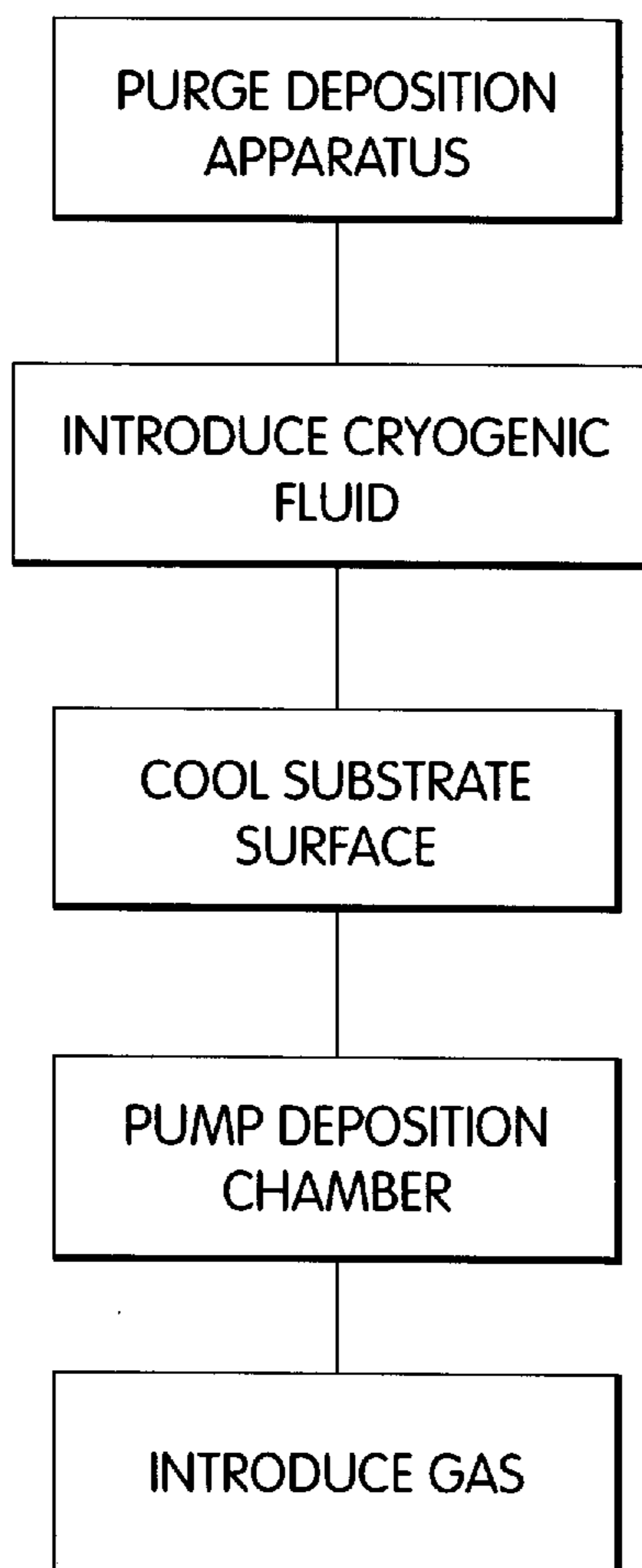


Fig. 4

1

METHOD AND APPARATUS FOR CRYOGENICALLY COOLING A DEPOSITION CHAMBER

BACKGROUND

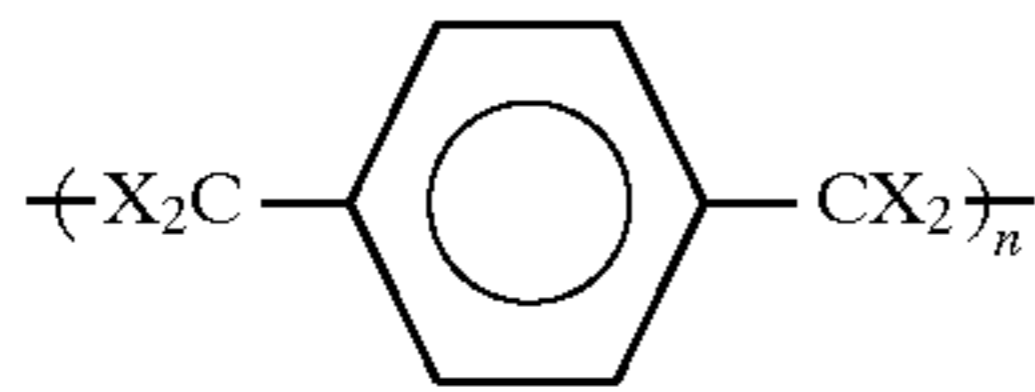
1. Field of the Invention

The present invention relates generally to a method and apparatus for cryogenically cooling a deposition chamber, and more specifically to such a method and apparatus that can preferentially cool the surface of a substrate onto which a gas is to be deposited.

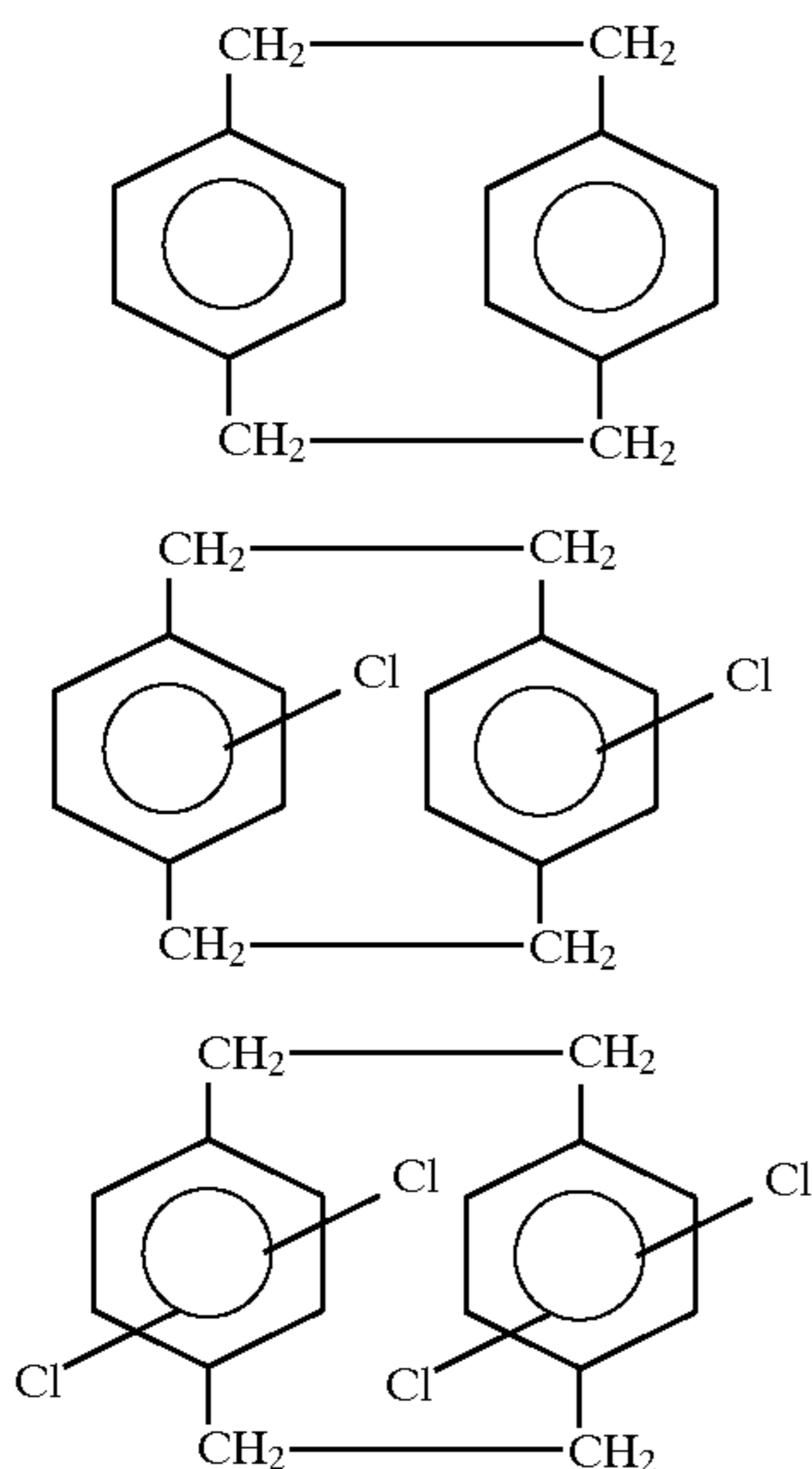
2. Discussion of the Related Art

Conformal coatings having low dielectric constants and high melting temperatures are desirable for many applications, including the medical, electronics and automotive industries. For example, the components of an automobile that are located beneath the hood (e.g., the carburetor) are exposed to various corrosive gases as well as temperatures in excess of 200° C. for extended periods of time.

Conventionally, layers of parylene polymers have been used as conformal coatings since some of these layers are known to have dielectric constants of about 2.3 and melting temperatures of about 540° C. Parylene polymers are poly-p-xylylenes which may be prepared with a parylene dimer. Parylene polymers generally have a structure:

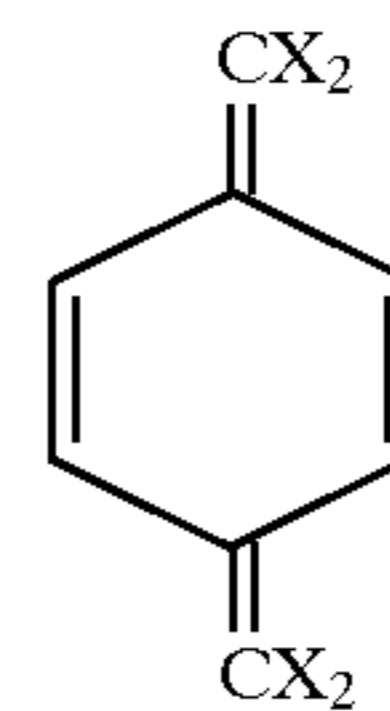


wherein X is typically a hydrogen atom or a halogen atom. The most common forms of parylene dimers include the following:



Typically, parylene polymer layers are formed by a vapor deposition method that is performed using a vacuum apparatus. In this method, generally referred to as the Gorham process, the parylene dimer is vaporized and the dimer bond is then cleaved to form parylene monomer having the structure:

2



5

The parylene monomer is then deposited onto the surface of a substrate and polymerization of the monomer occurs spontaneously to form the parylene polymer layer coating. This process and an apparatus appropriate for use with this process are disclosed in U.S. Pat. No. 5,538,758, which is herein incorporated by reference.

The parylene monomer preferentially deposits on relatively cool surfaces. Therefore, it is desirable within the art to provide a method and apparatus for depositing a gas, such as parylene monomer, onto cooled surfaces to yield a layer of material, such as a parylene polymer layer. It is also desirable to provide a method and apparatus for simultaneously depositing parylene monomer onto more than one substrate with minimal limitation on the surface area of the substrate(s).

SUMMARY OF THE INVENTION

In one illustrative embodiment, the present invention provides a method of depositing a gas onto a surface of a substrate. The substrate is disposed within the interior of the deposition chamber. The method comprises the steps of: (a) introducing a cryogenic fluid into the interior of the deposition chamber to cool the surface of the substrate; and (b) introducing the gas into the interior of the chamber to deposit the gas onto the surface of the substrate.

In another illustrative embodiment, the present invention provides a method of depositing parylene monomer within the interior of a deposition chamber of a parylene deposition system. The method comprises the steps of: (a) introducing a cryogenic fluid into the interior of the deposition chamber so that the cryogenic fluid cools at least the surface of a substrate disposed within the interior of the deposition chamber to a reduced temperature; (b) heating walls of the interior of the deposition chamber to a temperature greater than the reduced temperature of the surface of the substrate; and (c) introducing the parylene monomer into the interior of the deposition chamber so that the parylene monomer preferentially deposits onto the surface of the substrate.

In further illustrative embodiment, the present invention provides an apparatus for depositing a gas. The apparatus comprises: a deposition chamber; a pumping system, a source of cryogenic fluid, a gas source and at least one support mount for a substrate disposed within the interior of the deposition chamber. The pumping system reduces the pressure of the interior of the deposition chamber, and the pumping system is in fluid communication with the interior of the deposition chamber. The source of cryogenic fluid is in fluid communication with the interior of the deposition chamber. The gas source is in fluid communication with the interior of the deposition chamber.

In yet a further illustrative embodiment, the present invention provides an apparatus for depositing parylene monomer. The apparatus comprises: a deposition chamber; a vacuum pump, a source of cryogenic fluid, a source of parylene monomer and at least one support mount for a substrate disposed within the interior of the deposition chamber. The vacuum pump reduces the pressure of the interior of the first deposition chamber and is in fluid

communication with the interior of the first deposition chamber. The source of a cryogenic fluid is in fluid communication with the interior of the first deposition chamber. The source of parylene monomer is in fluid communication with the interior of the deposition chamber.

In another illustrative embodiment, the present invention provides a method of depositing a gas onto a surface of a substrate. The substrate is disposed within an interior of a deposition chamber. The method comprises the steps of: (a) cooling the surface of the substrate without clamping the substrate to a support; and (b) introducing the gas into the interior of the chamber to deposit the gas onto the surface of the substrate.

In contrast to certain related art systems, the present invention provides the advantage that clamping of the substrate (e.g., electro-clamping, gravitational clamping and the like) is not used to cool the surface of the substrate. Instead, the substrate can be cooled to a temperature sufficient to deposit a gas without clamping the substrate to the support or otherwise bringing the substrate into close contact with the support.

It is another advantage of the present invention that a relatively large surface area of one or more substrates can be cooled to appropriate temperatures prior to deposition of the parylene monomer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of one embodiment of an apparatus according to the present invention;

FIG. 2 is a cross-sectional view of another embodiment of an apparatus according to the present invention;

FIG. 3 is a cross-sectional view of yet another embodiment of an apparatus according to the present invention;

FIG. 4 is a flow chart of one embodiment of a method according to the present invention.

DETAILED DESCRIPTION

In one aspect, the present invention relates to a parylene monomer deposition apparatus **10** as shown in FIG. 1. Apparatus **10** includes a deposition chamber **12** having walls **11** with heaters **13** in thermal communication therewith. A substrate **14** is disposed within the interior of chamber **12** and held in place by a support mount **15**. Support mount **15** may take on any shape so long as it is capable of supporting substrate **14** during the coating process as described herein. Preferably, support mount **15** is chemically inert to substrate **14**. In alternate embodiments, substrate **14** may be coated using the tumbling technique known to those skilled in the art. In these embodiments, chamber **12** may not include mount **15**.

Pumping system **16** is in fluid communication with chamber **12** and can reduce the pressure of the interior of chamber **12** to pressures less than atmospheric pressure. Apparatus **10** further includes a cryogenic fluid source **18** that is in fluid communication with the interior of chamber **10** such that source **18** is capable of supplying a cryogenic fluid to the interior of chamber **12**.

A "cryogenic fluid" as used herein denotes a fluid that is capable of reducing the temperature of the surface of substrate **14** to temperatures below room temperature. Preferably, a cryogenic fluid can reduce the temperature of the surface of substrate **14** to less than about 40° C., more preferably less than about 10° C. and most preferably less than about -15° C. Furthermore, a cryogenic fluid should be chemically inert to substrate **14**. In addition, the cryogenic

fluid should have a water content low enough that exposure of the cryogenic fluid to substrate **14** according to the processes described herein results in substantially no water being left on the surface of substrate **14**. Preferably, prior to entering deposition chamber **12**, the water content of the cryogenic fluid is at most about 500 parts per million (ppm) water, more preferably at most about 200 ppm and most preferably at most about 5 ppm. It is to be noted that, due to their relatively low temperatures, cryogenic fluids usually freeze out other impurities, such as oils. Deposition of these impurities on the surface of the substrate can interfere with the processes of the present invention. Therefore, the comparatively low concentration of these impurities in cryogenic fluids is advantageous because it reduces the likelihood that contaminants will be deposited on the surface of the substrate during the deposition processes described herein.

A cryogenic fluid may be in the form of a liquid, a gas, a supercritical liquid or any combination thereof. Cryogenic fluids appropriate for use in the present invention include, but are not limited to, liquid nitrogen, liquid carbon dioxide, liquid helium and other such cryogenic fluids that are known to those skilled in the art as well as vapors thereof formed by heating as the cryogenic fluid is transferred from source **18** to the interior of chamber **12**, as discussed below.

Cryogenic fluid source **18** may be placed in fluid communication with chamber **10** using any device known to those skilled in the art. Such devices include, for example, pipes, tubes and other such devices that are known to those skilled in the art. Typically, a pipe or tube **20** is used to provide this fluid communication. In certain embodiments, one or more valves **22** may be used to control the flow of cryogenic fluid from source **18** to deposition chamber **12**. It is to be noted that, while FIG. 1 depicts source **18** disposed outside the interior of chamber **12**, in certain embodiments, source **18** may be located within the interior of chamber **12**. The location of cryogenic fluid source **18** is limited only in that it should be in fluid communication with the interior of source **12** and that it should not interfere with the pumping out of chamber **12** subsequent to cooling the surface of substrate **14** or the deposition of a gas on substrate **14**.

Pumping system **16** is usually at least one vacuum pump **24** placed in fluid communication with chamber **12** by a tube or a pipe **26**. In certain embodiments, vacuum pump **24** may be an oilless pump. To reduce the pressure of the interior of chamber **12**, a liquid nitrogen trap **28** may be placed between pump **24** and chamber **12**. Alternate embodiments will be readily apparent to those skilled in the art and are intended to be within the scope of the present invention.

The surface of substrate **14** may be formed from any material onto which parylene polymer may be deposited. These materials may include electrically conductive and electrically non-conductive materials. The particular material from which the surface of substrate **14** is formed depends upon the application, and such materials are known to those skilled in the art. For example, the surface of substrate layer **14** may be formed from organic materials or inorganic materials including, but not limited to, aluminum, iron, steel, molybdenum, aluminum oxide, titanium oxide, lead oxide, copper oxide, iron oxide, beryllium oxide, manganese oxide, tungsten oxide, tantalum oxide, vanadium oxide, silicones, natural rubbers, plastics, plastic composites, cellulosic materials, epoxy-containing compounds, thermosetting compounds, thermoplastic compounds, oxides of silicon (e.g., fly ash, hydrated silica, silica, quartz, aerogels, xerogels and fumed silica) and the like. Furthermore, the surface of substrate **14** may comprise gallium arsenide or other such semiconductors formed from more than one element.

The surface of substrate layer **14** may also be formed from a vacuum compatible liquid. By "vacuum compatible" it is herein meant to refer to a material that has a vapor pressure at the operating temperature of the vacuum chamber used such that the minimum pressure to which the vacuum chamber can be pumped is independent of the presence of the vacuum compatible material. One example of a vacuum compatible liquid is gamma-methacryloxypropyltrimethoxysilane.

In certain embodiments, substrate **14** may be a printed circuit board, a silicon backboard, a fiberglass backboard, a silicon wafer, paper, a key pad, a catheter, a pacemaker cover, a subcutaneous probe, a bird feather, a silicone O-ring, parts of a mechanical apparatus, such as an automobile, or the like.

FIG. 2 shows one embodiment of a deposition system **30** according to the present invention. System **30** includes deposition apparatus **10** having the features substantially as described above. System **30** further includes a vaporization chamber **32**, a pyrolysis zone **34** and a post-pyrolysis zone **36**. Vaporization chamber **32** is in fluid communication with pyrolysis zone **34**, and zone **34** is in fluid communication with post-pyrolysis zone **36**. Zone **36** is also in fluid communication with the interior of deposition apparatus **12**.

Vaporization chamber **32** includes a container **38** for holding parylene dimer. A heater **40** is in thermal communication with container **36**. Pyrolysis zone **34** includes at least one heater **42** for maintaining the walls **44** of zone **34** at elevated temperature. Post-pyrolysis zone **36** has baffles **46** which are maintained at a temperature of at most room temperature by cooling device **48**.

FIG. 3 is an alternate embodiment of an deposition system **50** in accordance with the present invention. Elements with the same reference number as disclosed above are substantially similar in apparatus **50**. Apparatus **50** further includes a load lock chamber **52** which is adjacent deposition chamber **12** of apparatus **10**. Load lock chambers appropriate for use in the present invention are known to those skilled in the art and are intended to be within the scope of the present invention.

Chamber **52** may be placed in fluid communication with deposition chamber **12** of apparatus **10** by opening a seal **54** between chamber **12** and chamber **52**. Alternatively, seal **54** may be closed to substantially prevent fluid communication between load lock chamber **52** and deposition chamber **12**.

In use, load lock chamber **52** is typically sealed from deposition chamber **12** while the pressure of chamber **12** is reduced (i.e., while chamber **12** is pumped out). The pressure of chamber **52** is maintained at a relatively high pressure while chamber **12** is pumped out (e.g., chamber **52** is kept at atmospheric pressure). Substrate **14** may be placed within chamber **52** and manipulated as desired. The pressure of chamber **52** may then be reduced, and seal **54** may be opened to place chamber **52** in fluid communication with chamber **12**. Substrate **14** may then be transferred to chamber **12** and subsequently have a parylene polymer layer formed on the surface of substrate **14**, as described herein. In certain embodiments, prior to transferring substrate **14** from chamber **52** to chamber **12**, substrate **14** may be cooled using a cryogenic fluid as described herein while it is within chamber **52**. Thus, for these embodiments, deposition chamber **12** need not be cooled in order to form a parylene polymer layer on the surface of substrate **14**. During the formation of the parylene polymer layer, seal **54** may be used to substantially prevent fluid communication between chamber **52** and chamber **12**. Alternatively, seal **54** may be open such that chamber **52** is in fluid communication with chamber **12**.

While particular apparatuses have been described herein, one skilled in the art would understand that at least certain aspects of these apparatuses may be varied or modified, and such variations and modifications are intended to be within the scope of the present invention. For example, rather than having heater **42** cleave the parylene dimer (described below), pyrolysis zone **34** may have a plasma source to cleave the parylene dimer. Such plasma sources are disclosed in, for example, Russian Patent Nos. RU 2,000,850 and RU 2,002,519. In some embodiments, apparatus **30** may not include post-pyrolysis zone **36**.

FIG. 4 is a flow chart of one embodiment of the method of the present invention. First, deposition apparatus **10** is purged with a gas at a temperature that does not substantially cool the surface of substrate **14** (e.g., room temperature). This gas should be chemically inert to substrate **14** and should introduce substantially no liquid water or water vapor into apparatus **10** during purging. Preferably, this gas has a water content of at most about 500 ppm, more preferably at most about 200 ppm and most preferably at most about 5 ppm. One example of such a gas appropriate for use in purging apparatus **10** is nitrogen. Other such gases known to those skilled in the art and are intended to be within the scope of the present invention.

A cryogenic fluid is then introduced into deposition apparatus **10** to reduce the temperature of the surface of substrate **14**. It is to be noted that, since deposition occurs over a period of time, it may be desirable to cool the surface of substrate **14** to a temperature slightly below the temperature that is desired for deposition. When introduced into the interior of deposition apparatus **10**, the cryogenic fluid may be in the form of a liquid, a gas, a supercritical fluid or a combination thereof. For example, while being transferred from source **18** to chamber **12**, some liquid nitrogen may boil and become nitrogen vapor. It is to be noted that, if the cryogenic fluid within the interior of chamber **12** is mostly a liquid, the cryogenic fluid need not entirely fill the interior of chamber **12** so long as the temperature of substrate **14** is ultimately reduced to a temperature that increases the rate of deposition of the gas (e.g., parylene monomer) on substrate **14**, as discussed below. In certain embodiments, however, it may be desirable to nearly or entirely fill the interior of chamber **12** when the cryogenic fluid is in the form of a liquid.

A period of time is allowed to pass so that the cryogenic fluid is effective in cooling the surface of substrate **14** to a temperature appropriate for deposition. It is to be noted that the temperature of walls **11** need not be cooled to this temperature. Preferably, subsequent to pumping out chamber **12**, as discussed below, walls **11** are allowed to heat up to a temperature higher than the temperature of the surface of substrate **14**. In some embodiments, heaters **13** may be used to increase the temperature of walls **11** to a temperature higher than the temperature of the surface of substrate **14**. Preferably, walls **11** are allowed to heat to a temperature at least from about 10° C. to about 20° C. higher than the surface of substrate **14**. More preferably, walls **11** are allowed to heat to a temperature of at least about 20° C. and most preferably from about 20° C. to about 40° C.

The pressure of chamber **12** is then reduced by using pumping system **16**. In this step, substantially all cryogenic fluid within the interior of chamber **12** is removed. Optionally, walls **11** of chamber **12** may be heated by heaters **13** to reduce the probability of subsequent gas deposition on walls **11**. It is to be noted that the relatively poor heat transfer that occurs in a vacuum reduces the thermal coupling between substrate **14** and walls **11** such that this method is

effective in heating walls **11** without substantially increasing the temperature of substrate **14**.

The gas is then introduced into the interior of chamber **12** and deposition occurs on the surface of substrate **14**. Preferably, during this step, the temperature of walls **11** is comparatively high so that deposition of the gas preferentially occurs on the surface of substrate **14**.

As discussed above, in alternate embodiments, deposition chamber **12** need not be cooled. Instead, substrate **14** may be placed within chamber **52**. Chamber **52** may then be purged and the cryogenic fluid may then be introduced to chamber **52**. The surface of substrate **14** can be cooled, and chamber **52** may then be pumped out. While keeping the surface of substrate **14** at an appropriate temperature for deposition as described herein, substrate **14** may then be transferred to chamber **12**. Deposition may then occur as described herein.

In certain embodiments, the method of the present invention may also include rotating substrate **14** to allow a more even deposition of the gas onto the surface of the substrate. Furthermore, in some embodiments, the method of the present invention may include using baffles to control the flow the cryogenic fluid into the interior of chamber **12** to provide a more even cooling of the surface of substrate **14**.

Having thus described certain embodiments of the present invention, various alterations, modification and improvements will be apparent to those skilled in the art. Such alterations, modifications and improvements are intended to be within the spirit and scope of the present invention. For example, various combinations of dry gases or cryogenic fluids may be used. In addition, a system may include more than one deposition chamber and/or more than one load lock chamber. Some or all of these load lock chamber(s) and/or deposition chambers may be capable of being placed in fluid communication with each other. In some embodiments, one or more load lock chambers and one or more deposition chambers may be cooled with a cryogenic fluid during the process of forming a parylene polymer layer on the surface of a substrate. Accordingly, the foregoing description is by way of example only and is not intended as limiting. The invention is limited only as defined by the following claims and the equivalents thereto.

What is claimed is:

1. A method of depositing a gas onto a surface of a substrate, the substrate being disposed within an interior of a deposition chamber, the method comprising the steps of:

(a) introducing a cryogenic fluid into the interior of the deposition chamber to cool the surface of the substrate; and

(b) introducing the gas into the interior of the chamber to deposit the gas onto the surface of the substrate.

2. The method of claim **1**, wherein step (a) includes cooling the surface of the substrate to a temperature of at most about 40° C.

3. The method of claim **1**, wherein step (a) includes cooling the surface of the substrate to a temperature of at most about 10° C.

4. The method of claim **1**, wherein step (a) includes cooling the surface of the substrate to a temperature of at most about -15° C.

5. The method of claim **1**, further comprising, between steps (a) and (b), the step of heating at least some portions of the interior of the deposition chamber other than the surface of the substrate.

6. The method of claim **5**, wherein the step of heating includes heating the portions of the interior of the deposition chamber other than the surface of the substrate to a temperature at least about 10° C. higher than a temperature of the surface of the substrate.

7. The method of claim **5**, wherein the step of heating includes heating the portions of the interior of the deposition

chamber other than the surface of the substrate to a temperature of at least about 20° C.

8. The method of claim **5**, wherein the step of heating includes heating the portions of the interior of the deposition chamber other than the surface of the substrate to a temperature of from about 20° C. to about 40° C.

9. The method of claim **1**, further comprising, between steps (a) and (b), the step of heating walls of the interior of the deposition chamber to a temperature at least about 20° C. higher than a temperature of the surface of the substrate.

10. The method of claim **9**, wherein step (a) includes cooling the surface of the substrate to a temperature of at most about 40° C.

11. The method of claim **10**, wherein step (a) introduces substantially no moisture into the interior of the deposition chamber.

12. The method of claim **1**, wherein step (a) introduces substantially no moisture into the interior of the deposition chamber.

13. The method of claim **1**, further comprising, between step (a) and step (b), the step of gasifying the cryogenic fluid so that substantially no liquid cryogenic fluid remains in the interior of the deposition chamber.

14. The method of claim **13**, further comprising, after the step gasifying, the step of removing the cryogenic fluid from the interior of the deposition chamber.

15. The method of claim **1**, further comprising, between step (a) and step (b), the step of removing the cryogenic fluid from the interior of the deposition chamber.

16. A method of depositing parylene monomer within an interior of a deposition chamber of a parylene deposition system, the method comprising the steps of:

(a) introducing a cryogenic fluid into the interior of the deposition chamber so that the cryogenic fluid cools at least a surface of a substrate disposed within the interior of the deposition chamber to a reduced temperature;

(b) heating walls of the interior of the deposition chamber to a temperature greater than the reduced temperature of the surface of the substrate; and

(c) introducing the parylene monomer into the interior of the deposition chamber so that the parylene monomer preferentially deposits onto the surface of the substrate.

17. The method of claim **16**, wherein step (a) cools the surface of the substrate to a reduced temperature of at most about 40° C.

18. The method of claim **17**, wherein step (b) heats the walls of the interior of the deposition chamber to a temperature at least about 20° C. higher than a temperature of the surface of the substrate.

19. The method of claim **18**, wherein step (c) includes the steps of:

gasifying parylene dimer to form gasified parylene dimer; and

cleaving the gasified parylene dimer to form the parylene monomer.

20. The method of claim **19**, wherein the step of gasifying includes vaporizing the parylene dimer.

21. The method of claim **19**, wherein the step of cleaving include pyrolyzing the parylene dimer.

22. The method of claim **19**, wherein the step of cleaving includes using a plasma.

23. The method of claim **16**, wherein step (a) includes cooling the surface of each of a plurality of substrates disposed within the interior of the deposition chamber.

24. The method of claim **16**, further comprising, between steps (a) and (b), the step gasifying the cryogenic fluid so that substantially no liquid cryogenic fluid remains in the interior of the deposition chamber.

25. The method of claim 24, further comprising, after the step gasifying, the step of removing the cryogenic fluid from the interior of the deposition chamber.

26. The method of claim 16, wherein step (a) includes cooling the surface of an automobile part.

27. The method of claim 16, further comprising, between step (a) and step (b), the step of removing the cryogenic fluid from the interior of the deposition chamber.

28. An apparatus for depositing a gas, comprising:

a deposition chamber having an interior and an exterior;
a pumping system for reducing a pressure of the interior of the deposition chamber, the pumping system being in fluid communication with the interior of the deposition chamber;

a support mount for a substrate, the support mount being disposed within the interior of the deposition chamber;

a source of cryogenic fluid in fluid communication with the interior of the deposition chamber; and

a gas source in fluid communication with the interior of the deposition chamber.

29. The apparatus of claim 28, wherein the pumping system comprises a vacuum pump.

30. The apparatus of claim 28, further comprising a plurality of support mounts for mounting a substrate.

31. The apparatus of claim 28, wherein the source of the cryogenic fluid comprises a tank of liquid nitrogen.

32. The apparatus of claim 28, wherein the source of cryogenic fluid comprises a container of liquid carbon dioxide.

33. The apparatus of claim 28, wherein the gas source is a source of parylene monomer.

34. The apparatus of claim 33, wherein the gas source comprises:

a chamber for gasifying parylene dimer to form gasified parylene dimer; and

a chamber for cleaving the gasified parylene dimer to form the parylene monomer, the chamber for cleaving being in fluid communication with the chamber for gasifying.

35. The apparatus of claim 28, further comprising a heater in thermal communication with portions of the interior of the deposition chamber other than the support.

36. The apparatus according to claim 28, further comprising a load lock chamber capable of being placed in fluid communication with the deposition chamber.

37. The apparatus according to claim 36, further comprising a seal disposed between the load lock chamber and the deposition chamber.

38. The apparatus according to claim 28, further comprising a load lock chamber capable of being placed in fluid communication with the first deposition chamber.

39. The apparatus according to claim 38, further comprising a seal disposed between the load lock chamber and the first deposition chamber.

40. An apparatus for depositing parylene monomer, comprising

a first deposition chamber having an interior and an exterior;

a vacuum pump in fluid communication for reducing a pressure of the interior of the first deposition chamber, the vacuum pump being in fluid communication with the interior of the first deposition chamber;

a support mount for mounting a substrate, the support being disposed within the interior of the first deposition chamber;

a source of a cryogenic fluid in fluid communication with the interior of the first deposition chamber; and

a source of parylene monomer in fluid communication with the interior of the deposition chamber.

41. The apparatus of claim 40, further comprising a plurality of support mounts for a substrate.

42. The apparatus of claim 40, wherein the source of cryogenic fluid comprises a tank of liquid nitrogen.

43. The apparatus of claim 40, wherein the source of cryogenic fluid comprises liquid carbon dioxide.

44. The apparatus of claim 40, wherein the source of parylene monomer comprises:

a chamber for gasifying parylene dimer to form gasified parylene dimer; and

a chamber for cleaving the gasified parylene dimer to form the parylene monomer, the chamber for cleaving being in fluid communication with the chamber for gasifying.

45. The apparatus of claim 40, wherein the source of parylene monomer comprises:

a vaporization chamber for forming vaporized parylene dimer; and

a pyrolysis chamber for forming the parylene monomer, the pyrolysis chamber being in fluid communication with the vaporization chamber.

46. The apparatus of claim 45, wherein the source of parylene monomer further comprises a post-pyrolysis chamber in fluid communication with the pyrolysis chamber and the first deposition chamber.

47. The apparatus of claim 40, further comprising a heater in thermal communication with the interior of the first deposition chamber, the heater being thermally isolated from the support mount.

48. The apparatus of claim 40, further comprising a second deposition chamber in fluid communication with the source of cryogenic fluid.

49. The apparatus of claim 40, wherein the at least one substrate comprises an automobile part.

50. A method of depositing a gas onto a surface of a substrate, the substrate being disposed within an interior of a deposition chamber, the method comprising the steps of:

(a) cooling the surface of the substrate without clamping the substrate to a support; and

(b) introducing the gas into the interior of the chamber to deposit the gas onto the surface of the substrate.

51. A method of depositing a gas onto a surface of a substrate, the substrate being disposed within an interior a load lock chamber, the method comprising the steps of:

(a) introducing a cryogenic fluid into the interior of the load lock chamber to cool the surface of the substrate to form a cooled substrate;

(b) transferring the cooled substrate to an interior of a deposition chamber; and

(c) introducing the gas into the interior of the deposition chamber to deposit the gas onto the surface of the substrate.

52. The method according to claim 51, further comprising the step of:

introducing a cryogenic fluid into the interior of the deposition chamber.

53. The method according to claim 52, further comprising the step of:

heating walls of the deposition chamber to a temperature greater than the temperature of the cooled substrate.